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SHOPE'S LANDFILL
REMEDIAL INVESTIGATION REPORT
BIOLOGICAL INVESTIGATION

Prepared for:

LORD CORPORATION
Erie, Pennsylvania

Prepared by:

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227 French Landing Drive
Nashville, Tennessee 37228
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July 1989

6284

ECKENFELDER INC.

July 10, 1989 6284

Mr. Eugene A. Miller
Environmental Project Manager
Lord Corporation
2000 West Grandview Boulevard
Erie, PA 16514

Dear Gene:

Enclosed is our report entitled "Shope's Landfill Remedial Investigation Report Biological Investigation". This report supplements the baseline report submitted in August 1987. However, the enclosure includes new information developed as the result of sampling in May 1989 and represents a different season of the year. Concerns raised by USEPA and PDER in reviewing the earlier report have been addressed.

Sincerely,

ECKENFELDER INC. (formerly AWARE Incorporated)

Billy G. Isom
Director
Aquatic Toxicology and Ecology

Enclosure

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INTRODUCTION

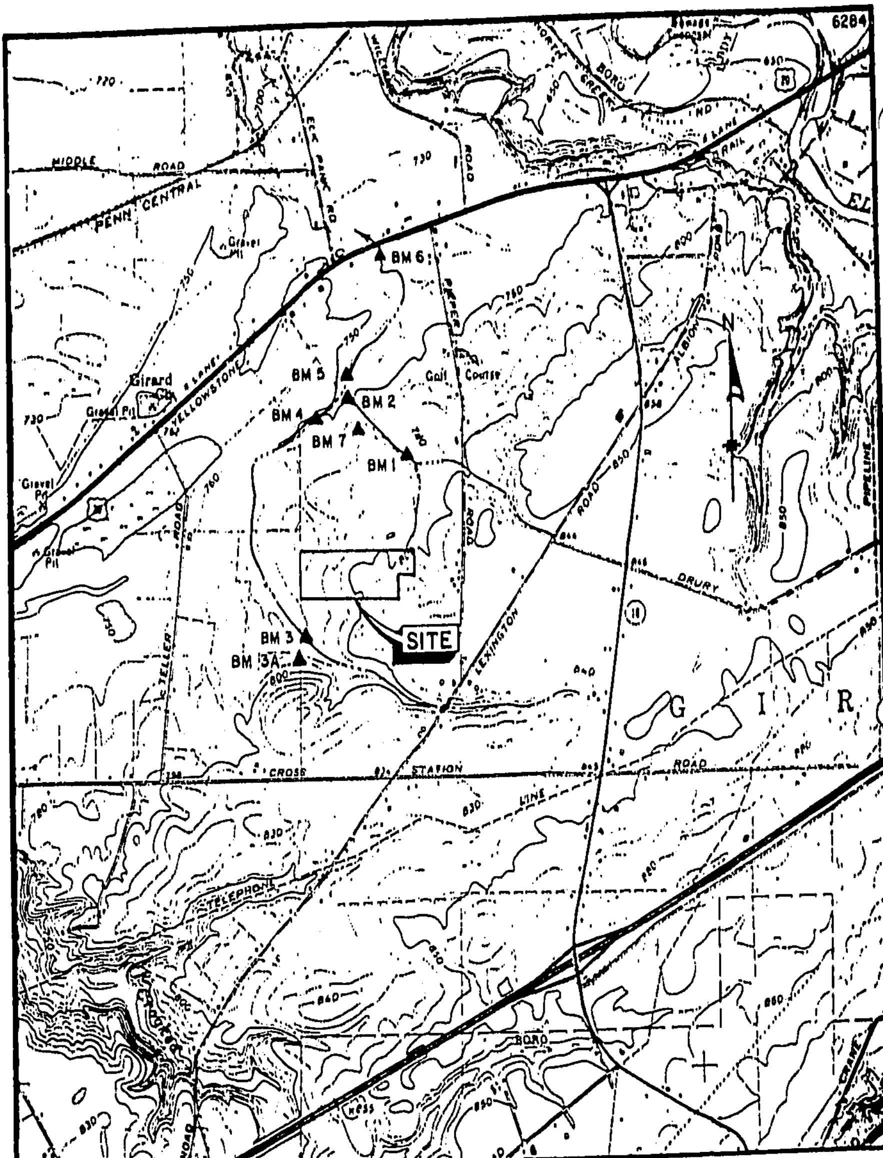
An initial investigation of the Shope's Landfill site, Erie County, Pennsylvania, was conducted September 16 and 17, 1986 to assess any impacts of the landfill on the benthic fauna of the receiving streams. The results of that investigation were presented in the Phase I RI for the site. Pennsylvania DER and USEPA have requested additional information regarding the site biota. In 1989, the terrain in the immediate area was also surveyed to determine the presence of wetlands habitat. Contact was made with the Commonwealth of Pennsylvania to determine the likelihood of endangered fish species occurring in the vicinity. The present study was conducted the week of May 8, 1989. The study was to provide additional information requested by Pennsylvania DER following the initial study.

The Shope's site is located in Erie County, Girard Township, Pennsylvania, on an eight acre tract due west of Pieper Road and south of U.S. Highway 20 (Figure 1). In the immediate vicinity of the landfill the area to the north, west, and southwest is secondary-growth deciduous forest. The area bordering the forested area is open fields. To the east and southeast of the landfill there are apple orchards and grape vineyards. A tributary to the southeast of the site flows west to northwest to north around the site. Another tributary originates just due north of the site as a wet weather spring and flows northwest away from the site for about one-half mile and merges with the larger unnamed tributary. This stream eventually flows into Elk Creek.

SAMPLING LOCATIONS

A map showing the study area and locations used for benthos collections in relation to Shope's Landfill is presented in Figure 1. The sampling stations were located in the following areas:

BM1 - Unnamed tributary approximately 100 yd upstream of a pond (lat. 41°58'53"; long. 80°21'00"), this station is downstream of the landfill,



LEGEND:

BM 4 ▲ BENTHOS SAMPLING LOCATIONS

SOURCE: ALBION (1959, REV. 1969)
PA. 7.5' QUADRANGLE

MAP LOCATION

2000 0 2000
scale feet

FIGURE I

BENTHOS SAMPLE STATIONS
SHOPE'S LANDFILL SITE
LORD CORP.
GIRARD TWP., PA.

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BM2 - Discharge from pond just upstream of confluence with tributary to Elk Creek (lat. 41°59'02", long. 80°21'14"),

BM3 - Unnamed tributary to Elk Creek approximately 1.5 miles upstream of intersection with U.S. Highway 20 (lat. 41°58'30"; long. 80°21'22"), this is a control station,

BM3A- Unnamed tributary about 200 yards west of BM-3, this is also a control station added in May 1989,

BM4 - Unnamed tributary to Elk Creek approximately 0.6 miles upstream of intersection with U.S. Highway 20 just upstream of confluence with pond discharge (lat. 41°59'02"; long. 80°21'18"), and any potential influence from the landfill,

BM5 - tributary to Elk Creek about 0.4 miles upstream of intersection with U.S. Highway 20 just downstream of confluence with pond discharge (lat. 41°59'06", long. 80°21'13"), and downstream from the landfill.

BM6 - tributary to Elk Creek just above intersection with U.S. Highway 20 (lat. 41°59'23"; long. 80°21'10") and fartherest downstream from the landfill.

BM7 - Seep approximately 100 ft south of pond (lat. 41°58'57", long. 80°21'14").

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STATION DESCRIPTIONS

Station BM1 (see Figure 1) - This station is located on a wet weather stream which drains part of the Shope's Landfill terrain and the adjacent golf course. The station is about 100 to 150 yd upstream of confluence with a pond. It was not stated in the 1986 description, but this stream appears to have been dug or modified in the past to receive drainage tile effluent from the golf course to the east and the fields to the west (see photographs of Station BM1).

The stream at this site was 2 ft wide and the water depth was 1 to 5 in. The tile field was actively flowing into the stream at the time of the study. It had been snowing and raining the previous few days and the soil was saturated. This stream is thought to flow intermittently, with little or no flow during summer months.

The station was accessed from the landfill road and then across an open field. There is a narrow vegetated band containing rose bushes, willows and weeds on both sides of the stream, up and downstream. The vegetated field to the west had been "bush-hogged", probably last fall. The golf course fairway comes almost up to the stream on the east.

Station BM2 (see Figure 1) - This station was used in 1986 but was dropped from the present survey, in agreement with Pennsylvania DER. This station was not comparable to other stations since it was located in the pond discharge on the golf course.

Station BM3 (see Figure 1) - This station along with BM3A, is to the southwest of the landfill. Station BM3 is located in a bushy, wooded area (see photographs of Station BM3). The station is about 1,000 ft upstream from surface water Station SW-2. Woods are located to the west and south of the station. There are open fields to the east and north of the station. Unlike BM1 this station appeared to be natural and not modified by man. The stream bed was 3 to 6 ft wide and very shallow; with a water depth of less than 6 in.

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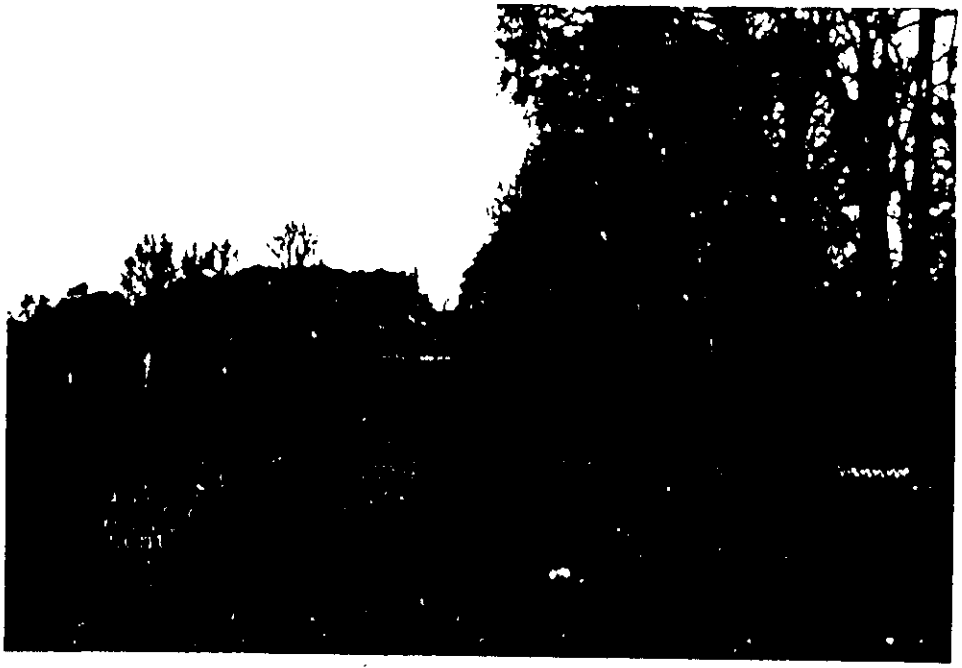
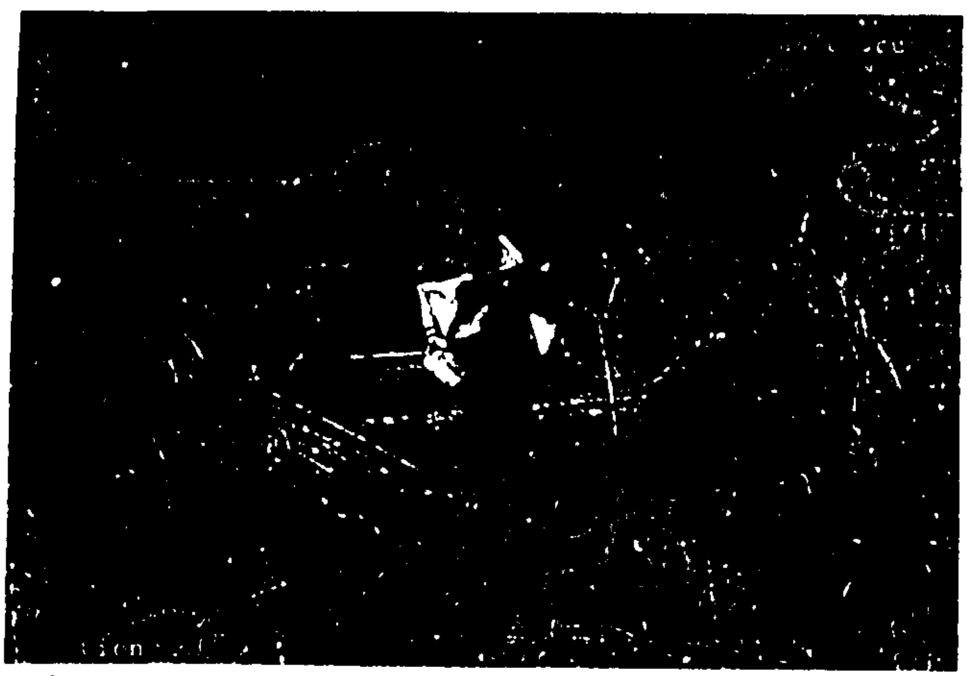


APPROACHING STATION BM1



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TILE DRAIN STATION BM1

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THE CONTROL STATION BM2

Station BM3A - (see Figure 1) This station was added in the field. It is on a tributary just to the west of BM3. This station appears to be totally separated from any potential site runoff. Substrate at the station was quite stable although the stream probably was modified sometime in the past. There are fields to the west and north and woods to the east toward BM3, which is between BM3A and the site. This station has not been affected by erosion sediments from recent farming as some other stations have experienced.

Station BM4 (see Figure 1) - This station is on the unnamed tributary to Elk Creek (see photographs of Station BM4). The station is upstream of the BM1 tributary confluence with the pond overflow and about 100 yd east of Well 29. The stream was about 4 ft wide, the water depth less than 10 in., mostly 5 to 6 in. deep. The stream bank was dominated by willows, wild rose bushes, and briars. It was quite evident that this stream portion had been modified within the last 50 yr or less to receive flow from tiles which drain adjoining fields. This is actually a central drainage ditch. Drain tiles can be seen at numerous locations along the stream ditch.

Station BM5 (see Figure 1) - This station is located in the unnamed tributary to Elk Creek just downstream of its confluence with the station BM1 stream and downstream of the pond. In 1986 the stream banks at this station were heavily vegetated. The banks are now totally clean and the stream bed appears to have been impacted by machinery activity (see photographs of Station BM5, note brush pile in background). The golf course fairway now passes almost over this station. There is no native vegetation influencing the stream at this location. There appeared to be increased sedimentation in the stream bed, probably due to dredging in the upstream pond area and farming activity.

Station BM6 (see Figure 1) - This station was on the unnamed tributary just upstream from U.S. Highway 20. The highway department had recently been in the stream with equipment to clean trees and underbrush from the bridge and highway right-of-way (see photographs of Station BM6, note debris that had been removed). The station was sampled just upstream of this influence. The stream was about 6 ft wide. Although the water was clear, the stream bottom was very silty on the sides. The center of the stream had been scoured, leaving a hard clay bottom.

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STATION BM4

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NOTE VEGETATION HAS BEEN REMOVED BM5

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STREAM DISTURBANCE STATION BM6

Station BM7 (see Figure 1) - This station was sampled in 1986 but was not sampled during this period as agreed on with Pennsylvania DER. This station was in a seep and was not comparable with other stations.

BACKGROUND

Macroinvertebrates or bottom fauna of streams have been used to assess productivity (standing crop) and stress in streams for over 50 yr in the United States. Standard methods for the use of macroinvertebrates to assess conditions of streams and other water bodies have been developed by USEPA (Weber, 1973), American Society for Testing and Materials (1988), and are included in "Standard Methods for the Examination of Water and Wastewater" (1985). In addition, the scientific literature is replete with benthic biological studies. The North American Benthological Society was formed in the early 1950's and is dedicated to the study and use of macroinvertebrates for assessing pollution of fresh and marine waters.

The alteration of the physical or chemical norms of an aquatic environment has the potential to influence nearly all organisms residing there (Goodnight 1973). A community represented by numerous species, with no particular numerical domination evident in the population, is usually indicative of an unstressed environment (Weber 1973). Conversely, a benthic community composed of a few species with large numbers of individuals typifies a stressed community from which intolerant species have been reduced or eliminated by a pollutant or substrate change. The populations of tolerant species expand due to reduced competition or increased resources, or both. The often dramatic benthic community shifts which can occur in stressed ecosystems are due to the varying sensitivities of the different macroinvertebrate species. Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), which spend most of their lives in an aquatic environment, are generally not tolerant of most types of pollution, whereas many flies (Diptera) and worms (Oligochaeta) are most tolerant of environmental stress conditions (Brinkhurst 1962, Beck 1977, Mason 1971, and Merritt and Cummins 1984).

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Stream reaches may be divided into several ecological categories depending upon whether or not they are subject to stressful agents and, if they are, to what extent or type. Stream reaches can usually be divided on the basis of the benthic fauna that is supported in that reach. Clean water streams with variable habitat features often have a high diversity of species with each species represented by a few individuals. Streams receiving organic pollution generally show a decrease in diversity and an increase in numbers of a few species (Gaufin and Tarzwell 1956), while streams receiving toxic products frequently show a decrease in both diversity and numbers (Cairns et al. 1971).

Increased sedimentation in streams is a problem most often the result of poor agriculture practices and construction activity in the vicinity of streams. The effects of increased sedimentation are varied, but the primary effect is habitat loss caused by the filling of cracks and crevices with sand and silt and a general decrease in habitat diversity.

Attention is usually focused on the macroinvertebrate species because they are more indicative of the relative health of a stream. In addition, macroinvertebrates are found in all habitats, are less mobile than some other groups of aquatic organisms such as fish, are easily collected, and most have relatively long periods of development in the aquatic environment. Thus, macroinvertebrate species can be used to indicate deleterious events that have occurred in an aquatic system over a period of time.

MATERIALS AND METHODS

Benthos

At each station three replicate quantitative samples were taken in a riffle area of the stream using a modified Surber Sampler which has a 270 micron mesh net and samples an area of 0.1 sq meter. Qualitative samples were also taken with a sweep net at each station. For the quantitative samples (Surber samples) the substrate was agitated to a depth of 6 in. where possible, and care taken to remove all organisms. The samples were transferred to plastic containers and preserved in the field with 10 percent formalin.

In the laboratory all benthic samples were washed in a 270 micron mesh screen. After washing, the macroinvertebrates were removed from the detritus and preserved in 85 percent ethanol. The organisms were identified to the lowest practical taxonomic level using available keys and counted (see Taxonomic References). Identifications were made with a stereomicroscope (7X to 60X). Slide mounts were made of the chironomids, simulids, oligochaetes and small crustaceans, and identifications were made with a compound microscope. The chironomids, simulids, and oligochaetes were cleared for 24 hrs in cold 10 percent KOH. Temporary mounts were made in glycerine and the animals returned to 80 percent ethanol after identification. When permanent mounts were desired, the organisms were transferred to 95 percent ethanol for 30 minutes and mounted in euperol.

Substrate Determination

A classification of substrate based on the size scale proposed by Wentworth (Compton 1962) was used to make field observations of the substrate present at each station in 1986. Therefore, sediments were not reclassified in 1989. The substrate was predominately silt and organic debris, such as leaves and twigs for example. Classification of detrital sediments is by grain diameter and is as follows:

Diameters	Approximate Inch Equivalents	Name of Loose Aggregate
>256 mm	>10 inch	Boulder
64 to 256 mm	2.5 to 10 inch	Cobble
2 to 64 mm	0.8 to 2.5 inch	Gravel
1/16 to 2 mm	0.002 to 0.8 inch	Sand
1/256 to 1/16 mm	0.00015 to 0.002 inch	Silt
<1/256 mm	<0.00015 inch	Clay

Community Structure Measures

Brower and Zar (1984) provide a detailed discussion of a variety of techniques for measuring community structure including diversity indices. The use of diversity indices is based upon the observation that normally undisturbed environments support communities with large numbers of species with no species present in overwhelming abundances. If the species of a disturbed community are ranked by numerical abundance, there will be relatively few species, but large numbers of individuals in these species. Mean diversity is affected by both "richness" of species (or abundance of different species) and by the distribution of individuals among the species. High species diversity indicates a highly complex community.

Species diversity was estimated using:

Shannon's Index of Diversity

$$H' = -\Sigma P_i \log P_i$$

Margalef's Diversity Index

$$D = (s-1)/\log N$$

Menhinick's Diversity Index

$$D = s/\sqrt{N}$$

Simpson's Dominance Index

$$SDI = \frac{\Sigma n_i (n_i - 1)}{N(N-1)}$$

Inverse Simpson's Dominance Index

$$d = \frac{1}{SDI} = \frac{N (N - 1)}{\Sigma n_i (n_i - 1)}$$

Brillouin Diversity Index

$$H = (\log N! - \Sigma \log n_i!)/N$$

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where P_i is the proportion of the total number of individuals occurring in species i, N is the total number of individuals in all species, s is the number of species, and n is the number of individuals in the ith species.

Diversity indices take into account both the species richness and the eveness of the individual's distribution among the species. Separate measures of these two components of diversity are often desirable. Richness can be expressed considering how close a set of observed species abundances is to those from an aggregation of species having maximum possible diversity for a given N and s (Brower and Zar 1984).

Evenness is calculated using

$E_s = D_s/D_{max}$ and $J = H/H_{max}$

$D_{max} = [(s-1/s)\ (N/N-1)]$

$H_{max} = (\log N_i - (s-r) \log C! - r \log (C+1)/N$

Where:

C = integer portion of N/s

r = (N/s) - C

Community similarity between sites is measured by the following:

$$\text{Jaccard Coefficient} = \frac{C}{S_1 + S_2 - C}$$

S = Species in each community

C = Species common to both communities

Sorensen Coefficient

$$S = \frac{2C}{S_1 + S_2}$$

Percent Similarity, for a two-community comparison, is calculated as follows:

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The number of individuals in each species is calculated as a portion of the total community population. The value for species i in community 1 (X_i) is compared to the value for species i in community 2 (y_i). The lower of the two is tabulated. This procedure is followed for each species. The tabulated list (of the lower of each pair of values) is summed. The sum is defined as the percent similarity of the two communities.

Index of Dissimilarity

$$I_1 = \sqrt{\Sigma(x_i - y_i)^2}$$

$$I_2 = \sqrt{\frac{\Sigma(x_i - y_i)^2}{s}}$$

$$I_3 = \sqrt{\left(\frac{x_i - y_i}{x_i + y_i}\right)^2} /s$$

x_i = number of individuals in species i in community 1

y_i = number of individuals in species i in community 2

s = number of different species in both communities.

Morisita's Index

$$I_m = \frac{2\Sigma x_i y_i}{(I_1+I_2)\ N_1\ N_2}$$

I_1 = Simpson's Dominance Index for community 1

I_2 = Simpson's Dominance Index for community 2

and

Horn Index of Community Overlap

$$R_o = \frac{H_4' - H_3'}{H_4' - H_5'}$$

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Definitions of the terms in the equation for the Horn Index are given in Appendix A.

Statistical Evaluation

Sampling efficiency of the field techniques was calculated via a statistical analysis of the quantitative samples. The mean number of organisms per sample, the standard deviation, the standard error, and the sampling precision of the mean were calculated for the benthic samples from each station (Elliot 1977). The sampling precision is the primary parameter evaluated and represents the percentage of the actual mean of the population within which the sample mean lies, and indicates how accurately the macroinvertebrate community was sampled. According to Elliott (1977), a sampling precision of 20 percent (80 percent confidence) or less is usually acceptable in biological studies. The sampling precision (D) is the ratio of the standard error to the arithmetic mean times 100:

$$D = (S.E./Mean)\ 100$$

Since three quantitative samples were taken in each area, some of the population estimates may not be sampled with 80 percent or greater confidence. As stated by Elliott (1977), the simplest solution to this problem is to take many samples (over 50 samples), but this is not usually an acceptable allocation of resources.

An analysis of variance (F test) was used to compare the stations using the number of organisms and species per sample. According to Sokal and Rohlf (1981), analysis of variance is a technique in statistics where the total variation in a set of data is partitioned into components associated with possible sources of variability. The relative importance of the different sources is then assessed by F-tests between each component of variation and the "error" variation. If the calculated F-value is greater than the tabular F-value at the 0.05 level of significance, then a difference between data sets is greater than the variation within a data set. Following the approach of

Chew (1977), mean separation tests were applied to separate and rank the mean values of each data set developed from benthic enumerations.

Biotic Index

Both the evenness and diversity indices are based on information of community structure and do not reflect any knowledge of the physiological attributes or ecological affinities of the organisms comprising the community (Howmiller and Scott 1977). Howmiller and Scott (1977) suggest the use of a trophic index for assessing ecological stress using Oligochaete species. After a 2 yr study of 53 Wisconsin streams, Hilsenhoff (1982) proposed using a biotic index of arthropod populations as a rapid method for evaluating water quality. Hilsenhoff (1987) expanded and improved his biotic index. This index which is a measure of organic and nutrient pollution, was used in this study.

To calculate the biotic index, species are assigned pollution tolerance values of 0 to 10. A value of 0 is assigned to species found only in unaltered streams of very high water quality, and a value of 10 is assigned to species known to occur in severely polluted or disturbed streams. Intermediate values are assigned to species that occur in streams with intermediate degrees of pollution or disturbance. Where species cannot be identified, genera are assigned values instead. The biotic index is calculated from the formula:

$$B.I. = n_i a_i / N$$

where n_i is the number of individuals of each species, a_i is the tolerance value assigned to that species, and N is the total number of individuals in the sample (Hilsenhoff 1982). The index is an average of tolerance values, and measures saprobity (pertaining to tolerance of organic enrichment) and to some extent trophism.

According to Hilsenhoff (1987) the calculated Biotic Index values reflect the following:

Biotic Index	Water Quality
0.00 - 3.50	Excellent
3.51 - 4.50	Very Good
4.51 - 5.50	Good
5.51 - 6.50	Fair
6.51 - 7.50	Fairly Poor
7.51 - 8.50	Poor
8.51 - 10.00	Very Poor

RESULTS

A list of the macroinvertebrate species collected from all sites and the total number of individuals within each species or species group are shown in Table 1. Also listed in Table 1 are the assigned pollution tolerance values for each species which were used to calculate Hilsenhoff's Biotic Index. Table 2 contains the actual number of organisms and species per individual sample. These data were used for the statistical comparisons. A summary of various population analyses including diversity, evenness, and biotic indicies is presented in Table 3. A presentation of the statistical comparison of the stations and analyses of sampling efficiency using mean number of organisms is shown in Table 4 while the same information based on mean number of species is presented in Table 5. Table 6 contains a statistical comparison of both the May 1989 and September 1986 data using mean number of organisms while Table 7 presents the same information based on mean number of species. Comparisons of the stations based on the May 1989 data using a variety of community comparison techniques are shown in Table 8. Table 9 also contains community comparisons of each station between periods. The results are discussed below.

DISCUSSION

Station BM1

A minimum of 27 species of benthic macroinvertebrates was collected and an estimate of 284 individuals per $0.3m^2$ was determined for Station BM1 (Table 1). The numbers of species and individuals were less during this period as compared to September 1986 (35 species and $1580/0.3m^2$). The dominant species occurring at the site in May 1989 were the small worms belonging to the family Naididae, two midges Chaetocladium piger and Diamesa sp., and the fingernail clam Sphaerium cf. simile (Table 1).

The biotic index value of 4.74 is according to Hilsenhoff (1987) and is representative of an aquatic community residing under "Good" water quality conditions. The diversity values (Table 3) for Shannon Diversity base 2 and evenness are indicative of a diverse community where no species truly dominates the system, values which Weber (1973) considers representative of unimpacted systems (to compare to previous studies use Shannon Diversity base 2).

In May 1989, when using number of individuals, Station BM1 was statistically different from BM4 (Table 4). When using mean number of species (Table 5), Station BM1 contains statistically less species than Station BM5. In terms of similarity (Table 8) Station BM1 was more comparable with Station BM3. When viewed through time, the community at Station BM1 in May 1989 was not very similar to that observed in September 1986 (Table 9). The differences are most probably a function of seasonal differences between periods. The same observation was also made for all other stations.

Station BM3

During the May 1989 period, the tributary at station BM3 had a community consisting of 34 species and 551 individuals per $0.3m^2$ (Table 1). The same number of species was collected in May 1989 as in September 1986. The total

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number of individuals taken in May 1989 was less than the 1233 taken in September 1986. The dominant species at this site was the stonefly Amphinemura delosa. Other abundant species included the mayfly Ephmerella cf. dorothea, and the midge Cladotanytarsus sp.

The community at Station BM3 is very diverse (Table 3). The values of diversity and evenness are values expected from an aquatic system under little or no measurable environmental stress (Weber 1973). The biotic index value calculated for this site was 3.93 and is, according to Hilsenhoff (1987) indicative of "Very Good" water quality. September 1986 survey data also indicted good water quality.

Statistically (Tables 4 and 5), BM3 was comparable to all sites. When community comparisons are made using similarity tests, Station BM3 is more comparable to Stations BM3A and BM5 (Table 8). With the exception of Station BM6, Station BM3 appears to have the most comparable community through time (Table 9).

Station BM3A

Station BM3A also has numerous species and a diverse aquatic fauna with a minimum of 40 species and 803 individuals per $0.3m^2$ of the natural substrate area (Table 1). As with station BM3, Amphinemura delosa, Ephemerella cf. dorothea, and Cladotanytarsus sp. are dominant components in the macroinvertebrate fauna. Another species of midge belonging to the Cricotopus tremulus species group was also abundant at this location (Table 1).

In terms of diversity, data taken at Station BM3A produced one of the highest values (Table 3). Conversely, the biotic index value calculated from the individual tolerance values and numbers of species yielded a value indicative of "Good" water quality (Hilsenhoff 1987). In terms of number of species and individuals present BM3A is statistically similar to all other sites (Tables 4 and 5). When community structure is compared, Station BM3A is more comparable to Station BM3 (Table 8).

Station BM4

Station BM4 in the May 1989 period had a community consisting of at least 38 species, the same number as taken in September 1986. The number of individuals per $0.3m^2$ taken in May 1989 (1559) was less than half that found in September 1986 (4125). The aquatic fauna at Station BM4 was dominated by seven species of chironomid midges and riffle beetle larvae, Dubiraphia sp., which was a situation slightly different from September 1986 when caddisflies were the dominant species.

As with the other sites the community at Station BM4 is very diverse with a good spread of individuals among the species (Table 3). Because of the high number of midge species which Hilsenhoff (1987) considers tolerant, the calculated biotic index value (Table 3) was high and reflects "Fairly Poor" water quality, a condition also found in the September 1986 survey. This condition should be expected in a small stream draining areas of heavy agricultural use. A situation exists where enrichment is producing increases in population numbers but not to the point where diversity is impacted.

Statistically, Station BM4 was significantly greater in number of individuals present than Station BM1 in May 1989 (Table 4), while the number of species was not significantly different from any other site (Table 5). According to data shown in Table 8, the community at BM4 is more comparable to Station BM6 and least comparable to BM1. A comparison of the May 1989 to September 1986 period (Table 9) indicates that for Station BM4 the two periods were not very comparable. Again this low degree of comparison is a function of two different seasons and was generally observed at all stations.

Station BM5

The aquatic populations at Station BM5 during the May 1989 period consisted of at least 40 species and numbers as high as 843 per $0.3m^2$. The same station during the September 1986 period had 29 species and 1161 individuals per $0.3m^2$.

The community in May 1989 was dominated by the three midge species Microtendipes sp., Cricotopus tremulus species group, and Cladotanytarsus sp.

As with the other sites the community at Station BM5 is very diverse (Table 3). The biotic index value of 5.94 calculated for this site is reflective of "Fair" water quality (Hilsenhoff 1987). Note in the photographs of Station BM5 that removal of stream-side vegetation has destabilized the stream bottom to some extent. The biotic index value for the September 1986 period was also indicative of "Fair" water quality. During the May 1989 period Station BM5 was comparable to all other sites when using mean number of organisms (Table 4). When mean number of species was used for comparison Station BM5 was significantly greater than Station BM1 (Table 5). When community structure was compared (Table 8), Station BM5 was more comparable to stations BM3 and BM3A, and least comparable to Station BM1.

Station BM6

The aquatic community at Station BM6 in May 1989 consisted of a minimum of 28 species and 553 individuals per $0.3m^2$ (Table 1). In comparison, the same station in September 1986 had 40 species and 1135 individuals per $0.3m^2$. The fauna at this site during the May 1989 period was dominated by the midges Cladotanytarsus sp. and Microtendipes sp.

The diversity and evenness values for the community at Station BM6 are fairly high, indicating a good spread of the individuals among the various species (Table 3). The biotic index value for the May 1989 period at this location indicates that the community is residing under "Fairly Poor" water quality conditions (Hilsenhoff 1987). It is obvious from the photographs at Station BM6 that activities in the stream have affected the habitat of this station. The biotic index value for the September 1986 period was reflective of "Good" water quality, indicating that the community of the May 1989 period was dominated by what Hilsenhoff (1987) considers more tolerant species.

In may 1989, Station BM6 was statistically comparable to all other sites when number of species and organisms were used to separate the various sites. When community similarity tests are used to compare the sites Station BM6 is more comparable to Station BM4 and least comparable to Station BM1 (Table 8).

According to data shown in Table 9, Station BM6 appears to be the most comparable site between the two periods.

SUMMARY

In summary, during the May 1989 period, a minimum of 71 species were collected from all sites (Table 1). Stations BM3A and BM5 had the most species present with 40 each., while stations BM1 (27) and BM6 (28) had the least. Highest standing crop (as individuals per $0.3m^2$) was observed at Station BM4 (1559 per $0.3m^2$).

When Hilsenhoff's Biotic Index (Table 3) was used to assess the sites, the locations with the most intolerant populations (clean water species) were stations BM3 (3.93) and BM1 (4.74), while stations BM6 (6.80) and BM4 (6.72) had the most tolerant aquatic communities. Diversity and evenness values of all locations were high indicting that a fairly even distribution of individuals among the various species was present at all locations.

A statistical comparison of the May data using mean number of organisms (Table 4) indicates that Station BM4 had a significantly greater number of individuals than Station BM1. A comparison using mean number of species (Table 5) shows that Station BM5 had a significantly higher number of species than Station BM1. A statistical comparison of all sites for both periods (Table 6) using mean number of organisms demonstrates that stations BM2 and BM4 in September 1986 were significantly greater than all other stations when using Duncan's Multiple Range test and Student-Newman-Keul's test. A statistical comparison using mean number of species (Table 7) produced three groupings with the most revealing differences being that Station BM4 in September 1986 had a greater number of species than stations BM1 and BM3 in May 1989.

A comparison of the stations using community structure (Table 8) shows stations most similar in species composition to be BM3, BM3A, and BM5. The least similar sites in species composition are BM1 and BM6. A comparison of the stations between periods (Table 9) indicates a vast difference in species composition which is probably a function of seasonal differences since this observation generally held for all stations.

WETLANDS

The three parameters that are used to define and delineate wetlands are hydrophytic vegetation, hydric soils, and wetlands hydrology (USEPA 1988). Hydrophytic vegetation includes any macroscopic plant life growing in water or on substrate that is at least periodically deficient of oxygen as a result of excessive water content (USEPA 1988). Hydric soils are soils that are saturated, flooded or ponded, long enough during the growing season to develop anaerobic conditions in the upper part (USEPA 1988). Wetland hydrology is the sum total of wetness characteristics in areas that are inundated or have saturated soils for a sufficient duration to support hydrophytic vegetation (USEPA 1988).

As noted in describing the stations sampled the unnamed tributary on which BMI is located and the main unnamed tributary to Elk Creek north and west of the Shope's site were undoubtedly altered by man in past decades. The tributaries are really central ditches that are interceptors for tiles draining the soils of the nearby fields and golf course. It is our judgment that probably the golf course and the large plant nursery to the north and west of the site was all hardwood swamp that has been cleared and drained in past times. Currently, there is an area immediately to the southwest of the site that is still a hardwood swampy area and is so designated on the topographic map (February 1989). However, this area is anticipated to be outside the range of impact of further remediation.

The National Wetlands Inventory map for the Albion, Pennsylvania quadrangle indicates that there are four palustrine open water areas north of the site on the golf course. One area is a pond or gravel pit on the golf course property. The other three areas are almost certainly presently or former water hazards on the golf course. There are no wetlands in that area.

Under the present system of ditches and tile fields there are no wetlands north of the site, only the golf course and fields. All of the land in this area is either part of the golf course or fields. Under the revised Chapter 105 (April 7, 1989) of the Department of Environmental Resources, Commonwealth of Pennsylvania, Rules and Regulations Section 105.12, these lands are exempt from wetlands permit requirements, "(iii) Existing field tile drainage systems that were constructed prior to December 23, 1985 for cropping, management or maintenance operation for crop production and have been in such use for the past five years," and other stipulations are exempt.

ENDANGERED SPECIES

Contact was made with Mr. Roger Kenyon concerning the known distribution of possible endangered fish species. Neither of the two species reported to occur in this region are known to occur in the Elk Creek drainage basin.

Percina macrocephala (Longhead Darter) is not recorded from Western Pennsylvania. Ammocrypta pellucida (Eastern Sand Darter) occurs in Lake Erie and some sandy bottom streams which are direct tributaries to the Lake.

Fathead minnows were relatively numerous in the unnamed tributaries and two small bluegill sunfish were noted at station BM6 near Highway 20. There was no indication of any other fish being present in the streams and there is no known fishery in the system.

CONCLUSIONS

Station BM1 has an assemblage of aquatic organisms indicating good water quality according to the Hilsenhoff biotic index. This station along with BM3 had the most intolerant species. However, this station is generally different from other stations except the control Station BM3 with which it is most comparable.

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Station BM5 is also comparable with BM3 and BM3A, the controls. Basically, this means that in the future data from Stations BM1 and BM5, which are both downstream from the Shope's site, should be compared with the control stations and not with each other. The control stations BM3 and BM3A have biota indicating good water quality as does BM1 the station immediately downstream from the landfill. Stations BM5 and BM6 have been affected by recent activities in the stream and removal of vegetation along the banks at both stations with resulting increase in sedimentation.

Species and number of organisms collected in September 1986 and May 1989 were significantly different due to the effects of season. This means that future comparisons should be done only for the same season.

Overall the aquatic biota in the unnamed tributaries indicates that water quality is fair to excellent with a good number of species and numbers of organisms. According to the Hilsenhoff index (1987) the following water quality conditions were found:

Station	Location	Water Quality Condition	Comments
BM1	Downstream of Landfill	Good	Stream bottom stable
BM3	Control	Very Good	Stream bottom stable
BM3A	Control	Good	Stream bottom stable
BM4	Above Potential Influence of landfill	Fairly Poor	Stream affected by agricultural runoff
BM5	0.4 miles upstream of Highway 20	Fair	Stream bank denuded
BM6	At Highway 20	Fairly Poor	Station impacted by local activities

In the process of collecting benthic samples numerous fathead minnows were observed and released. This was the only fish species observed with the exception of two small bluegills noted at station BM6. There is no fishery in these streams and, therefore, no food pathway for chemical transport to humans even if chemicals were present.

There are no presently recognized wetlands in the vicinity of the unnamed tributary on which station BM1 is located. There are some areas upstream of the control station BM3 which include some hardwood swamp environment. This area is not on the National Wetlands inventory. The area is above and outside of any planned activities.

No endangered species are known to exist in or near the streams.

Land on the golf course North of the site, adjacent fields and the plant nursery to the north and west of the site are drained by tiles which deposit their flow in the unnamed streams which are either of manmade origin or have been drastically modified by man in historic times.

There is no evidence of any impacts to biota in either stream from former activities at Shope's Landfill.

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TABLE 1

AQUATIC MACROINVERTEBRATE SPECIES COLLECTED FROM SITES NEAR SHOPE'S LANDFILL, MAY 9, 1989 (No./0.3m^2).

SPECIES	TOLERANCE VALUE	BM1	BM3	BM3A	BM4	BM5	BM6
PLATYHELMINTHES							
Turbellaria							
Planariidae							
<u>Cura</u> <u>foremanii</u>	a	9	4	5	1	10	
NEMATODA	a			1			
ANNELIDA							
Hirudinea							
Erpobdellidae							
<u>Placobdella</u> <u>papillifera</u>	a			1			
Oligochaeta							
Lumbriculidae							
<u>Lumbriculus</u> sp.	a	2	2			1	
Naididae	a	48				1	
Tubificidae	a				5		10
<u>Limnodrilus</u> <u>hoffmeisteri</u>	a	9	6	9		20	
ARTHROPODA							
Arachnoidae							
Hydrachnidae							
<u>Hydrachna</u> sp.	a					1	
Crustacea							
Amphipoda							
Gammaridae							
<u>Gammarus</u> sp.	8	5					
Talitridae							
<u>Hyallela</u> <u>azteca</u>	8			2		4	
Decapoda							
Cambaridae	10					2	2
Insecta							
Ephemeroptera							
Baetidae							
<u>Baetis</u> <u>tricaudatus</u>	6		1	5		2	
Caenidae							
<u>Caenis</u> <u>sp.</u>	7				1	5	25
Ephemerellidae							
<u>Ephemerella</u> cf. <u>dorothea</u>	1		71	90	1	3	
Leptophlebiidae							
<u>Paraleptophlebia</u> sp.	1	23	17	2	3	[illegible]	3

TABLE 1. (Cont.)

		BM1	BM3	BM3A	BM4	BM5	BM6
Siphlonuridae							
Ameletus lineatus	0		1				
Odonata							
Aeshnidae							
Boyeria vinosa	2		1	2		4	
Calopterygidae							
Calopteryx sp.	5						1
Plecoptera							
Nemouridae							
Amphinemura delosa	3	13	172	119	4	52	2
Perlidae							
Isoperla sp.	2			5	4	3	
Trichoptera							
Hydropsychidae							
Cheumatopsyche sp.	5			1	25		1
Diplectrona modesta	0		29	16			
Hydropsyche betteni-depravata sp. gp.	6			5	14		2
Symphitopsyche sp.	6		6	1			
Symphitopsyche cf. *sparna*	6			2	10		
Limnephilidae	3	2	1				
Neophylax sp.	3		2	6			
Psychoglypha subborealis	0	1		1			
Coleoptera							
Elmidae							
Dubiraphia sp.	8		1	21	188	3	22
Dubiraphia vittata	8	1		4	4	3	1
Optioservus sp.	4		5	12	12	4	3
Optioservus ovalis	4		6	10			
Stenelmis sp.	5		2	18	23	23	9
Stenelmis cf. *mirabilis*	5				1	17	1
Hydrophilidae							
Berosus sp.	5				1	1	
Megaloptera							
Sialidae							
Sialis sp.	4				1		
Diptera							
Ceratopogonidae							
Palpomyia/Bezzia sp. gp.	6	18	1	4	8	7	1
Chironomidae							
Chaetocladius piger sp.gp.	6	63	3	39	[illegible]	6	7
Cladotanytarsus sp.	7		91	117	[illegible]	[illegible]	44
Conchapelopia sp.	6	2	17	48	97	31	36
Cricotopus bicinctus	7				7		
Cricotopus tremulus sp. gp.	7		1	100	271	123	26

TABLE 1. (Cont.)

		BM1	BM3	BM3A	BM4	BM5	BM6
Cryptochironomus fulvus	8		1		149		48
Diamesa sp.	5	32		9		42	
Microtendipes sp.	6		2			278	106
Orthocladius sp.	6					6	
Orthocladius (*Euorthocladius*) sp.	6					6	
Paracladopelma undine	7		10	79	10	11	22
Parametriocnemus lundbecki	5	2	1	8		3	
Paratendipes sp.	8		11		11	11	56
Polypedilum illinoense	6		5	26	99	28	8
Rheocricotopus robacki	6	1			7		
Rheotanytarsus sp.	6			1			
Tanytarsus sp.	6	4	35		244	4	7
Empididae	6			1		3	3
Muscidae	6	1					
Psychodidae							
Pericoma sp.	4	1					
Psychoda sp.	4				1		
Simuliidae							
Prosimulium mixtum	4	2					3
Simulium sp.	4	1	8	20		19	
Tabanidae							
Chrysops sp.	6	1	13	3	6	2	
Tipulidae							
Antocha sp.	3			1			
Dicranota sp.	3				1		
Hexatoma sp.	2				1		
Limnophila sp.	3	3					
Pseudolimnophila sp.	2	5	1		1		3
Tipula sp.	4	5	1	2		2	
Collembola	a	1			1		
MOLLUSCA							
Gastropoda							
Physidae							
Physella sp.	a			2	1	2	
Planorbidae							
Helisoma sp.	a				3		
Pelecypoda							
Sphaeriidae							
Sphaerium cf. *simile*	a	29	23	5	24	1	
TOTAL NO./0.3m[2]		284	551	803	[illegible]	813	[illegible]
TOTAL NO. OF SPECIES		27	34	40	38	40	28

[a]No tolerance value assigned

TABLE 2

A SUMMARY OF THE ANALYSES OF THE MACROINVERTEBRATE SAMPLES AT EACH STATION, TRIBUTARY TO ELK CREEK, ERIE COUNTY, PENNSYLVANIA MAY 9, 1989

ANALYSES	STATION					
	BM1	BM3	BM3A	BM4	BM5	BM6
Surber A						
No. of Organisms	188	120	114	449	120	357
No. of Species	17	13	23	15	22	21
Surber B						
No. of Organisms	38	338	337	786	161	125
No. of Species	14	24	18	20	29	15
Surber C						
No. of Organisms	58	121	360	276	613	134
No. of Species	12	13	27	26	20	17

TABLE 3

POPULATION ANALYSES, TRIBUTARY TO ELK CREEK, ERIE COUNTY, PENNSYLVANIA, MAY 9, 1989

PARAMETER	STATION					
	BM1	BM3	BM3A	BM4	BM5	BM6
Diversity						
Margalef Diversity	10.598	12.039	13.426	11.588	13.330	9.844
Menhinick Diversity	1.602	1.448	1.412	0.962	1.378	1.191
Simpson Dominance	0.114	0.152	0.090	0.110	0.154	0.134
Simpson Diversity	0.886	0.848	0.910	0.890	0.846	0.866
Inverse Simpson Dominance	8.768	6.561	11.101	9.081	6.474	7.476
Shannon Diversity (Base 10)	1.089	1.046	1.199	1.082	1.080	1.047
(Base E)	2.507	2.408	2.762	2.491	2.487	2.412
(Base 2)	3.617	3.473	3.985	3.593	3.588	3.479
Brillouin Diversity (Base 10)	1.025	1.002	1.161	1.062	1.044	1.009
(Base E)	2.361	2.308	2.674	2.446	2.404	2.324
(Base 2)	3.407	3.330	3.857	3.528	3.468	3.353
EVENNESS						
Simpson Diversity	0.917	0.872	0.932	0.913	0.866	0.897
Inverse Simpson Dominance	0.295	0.181	0.264	0.233	0.154	0.254
Shannon Diversity	0.761	0.683	0.749	0.695	0.674	0.724
Brillouin Diversity	0.733	0.674	0.746	0.684	0.670	0.699
Biotic Index	4.74	3.93	5.05	6.72	5.94	6.80

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TABLE 4

STATISTICAL ANALYSES OF SAMPLING EFFICIENCY AND COMPARISON OF THE STATIONS USING MEAN NUMBER OF ORGANISMS, TRIBUTARY TO ELK CREEK, ERIE COUNTY, PENNSYLVANIA, MAY 9, 1989

ANALYSES	STATION BM1	BM3	BM3A	BM4	BM5	BM6
No. of Samples	3	3	3	3	3	3
Mean No. of Organisms	94.6	193.0	270.3	503.7	298.0	205.3
Standard Deviation	81.4	125.6	135.9	259.4	273.6	131.4
Standard Error	47.0	72.5	78.4	149.7	157.9	75.9
Precision of the Sampling Mean	49.7%	37.6%	29.0%	29.7%	53.0%	36.9%

Calculated F = 1.72

[a]Duncan's Multiple Range Means Separation Test

BM4	A	
BM5	A	B
BM3A	A	B
BM6	A	B
BM3	A	B
BM1		B

[a]Means separation test used include Duncan's Multiple Range, Student-Newman-Keuls, Student Maximum Modulus and Scheffe's Test, means with the same letter are not significantly different. Difference was seen only with Duncan,s Multiple Range Test.

TABLE 5

STATISTICAL ANALYSES OF SAMPLING EFFICIENCY AND COMPARISON OF THE STATIONS USING MEAN NUMBER OF SPECIES, TRIBUTARY TO ELK CREEK ERIE COUNTY, PENNSYLVANIA, MAY 9, 1989

ANALYSES	STATION					
	BM1	BM3	BM3A	BM4	BM5	BM6
No. of Samples	3	3	3	3	3	3
Mean No. of Species	14.3	16.7	22.7	20.3	23.7	17.7
Standard Deviation	2.5	6.3	4.5	5.5	4.7	3.1
Standard Error	1.4	3.7	2.6	3.2	2.7	1.8
Precision of the Sampling Mean	10.2%	21.9%	11.5%	15.7%	11.5%	1.0%

Calculated F = 1.83

[a]Duncan's Multiple Range Means Separation Test

BM5	A	
BM3A	A	B
BM4	A	B
BM6	A	B
BM3	A	B
BM1		B

[a]Means separation tests used include Duncan's Multiple Range, Student-Newman-Keuls, Student Maximum Modulus and Scheffe's Test, means with the same letter are not significantly different. Difference was seen only with Duncan's Multiple Range Test.

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If the page filmed in this frame is not as readable or legible as this label, it is due to substandard color or condition of the original page.

TABLE 6

STATISTICAL COMPARISONS[a] OF STATIONS FROM BOTH PERIODS[b], USING MEAN NUMBER OF ORGANISMS, TRIBUTARY TO ELK CREEK, ERIE COUNTY, PENNSYLVANIA

DUNCAN'S MULTIPLE RANGE	STATION	SNK	STATION	SMM			STATION	SCHEFFE'S TEST		STATION
A	S4	A	S4		A		S4		A	S4
A	S2	A	S2	B	A		S2	B	A	S2
B	S1	B	S1	B	A	C	S1	B	A	S1
B	M4	B	M4	B	A	C	M4	B	A	M4
B	S3	B	S3	B		C	S3	B	A	S3
B	S5	B	S5	B		C	S5	B	A	S5
B	S6	B	S6	B		C	S6	B	A	S6
B	M5	B	M5	B		C	M5	B	A	M5
B	M3A	B	M3A	B		C	M3A	B	A	M3A
B	M6	B	M6			C	M6	B	A	M6
B	M3	B	M3			C	M3	B	A	M3
B	M1	B	M1			C	M1	B		M1

[a]Means separation tests used include Duncan's Multiple Range, Student- Newmans-Keuls, Student Maximum Modulus and Scheffe's Test, means with the same letter are not significantly different.

[b]S designates stations collected in September while M indicates May samples.

TABLE 7

STATISTICAL COMPARISONS[a] OF STATIONS FROM BOTH PERIODS[b], USING MEAN NUMBER OF SPECIES, TRIBUTARY TO ELK CREEK, ERIE COUNTY, PENNSYLVANIA

Duncan's Multiple Range Test

Grouping			Station
	A		S4
B	A		S1
B	A		M5
B	A		M3A
B	A		S3
B	A		S6
B	A	C	M4
B	A	C	S5
B	A	C	S2
B	A	C	M6
B		C	M3
		C	M1

[a]Means sepatation tests used included Duncan's Multiple Range, Student-Newmans-Keul's, Student Maximum Modulus and Scheffe's Test, means with the same letter are not significantly different. Difference was seen only with Duncan's Multiple Range Test.

[b]S designates stations collected in September while M indicates samples taken in May.

TABLE 8

COMMUNITY SIMILARITY VALUES, TRIBUTARY TO ELK CREEK, ERIE COUNTY, PENNSYLVANIA, MAY 9, 1989

	BM1	BM3	BM3A	BM4	BM5	BM6
<u>Jaccard</u> <u>Coefficient</u>						
BM1		0.356	0.288	0.250	0.340	0.196
BM3			0.542	0.385	0.542	0.378
BM3A				0.393	0.538	0.308
BM4					0.444	0.500
BM5						0.417
<u>Sorensen</u> <u>Coefficient</u>						
BM1		0.525	0.448	0.400	0.507	0.327
BM3			0.703	0.556	0.703	0.548
BM3A				0.564	0.700	0.471
BM4					0.615	0.667
BM5						0.588
<u>Percent</u> <u>Similarity</u>						
BM1		18.284	16.507	12.567	17.848	5.587
BM3			57.468	30.323	32.102	29.209
BM3A				49.335	51.099	38.309
BM4					40.196	46.454
BM5						49.082

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TABLE 8. (Cont.)

	BM3	BM3A	BM4	BM5	BM6
Dissimilarity Index I_1					
BM1	220.420	242.085	510.683	337.489	222.443
BM3		156.333	500.226	341.564	238.600
BM3A			434.378	314.522	227.064
BM4				502.828	443.229
BM5					229.465
Dissimilarity Index I_2					
BM1	32.858	33.571	70.819	47.728	32.797
BM3		22.565	69.369	49.301	35.568
BM3A			58.046	43.616	31.488
BM4				68.426	66.819
BM5					33.120
Dissimilarity Index I_3					
BM1	0.886	0.904	0.925	0.887	0.939
BM3		0.802	0.901	0.812	0.884
BM3A			0.854	0.751	0.878
BM4				0.841	0.840
BM5					0.836
Morisita Index					
BM1	0.181	0.206	0.178	0.093	0.034
BM3		0.752	0.290	0.283	0.356
BM3A			0.553	0.423	0.485
BM4				0.363	0.538
BM5					0.734

TABLE 8. (Cont.)

Horn Index	BM3	BM3A	BM4	BM5	BM6
BM1	0.341	0.341	0.289	0.304	0.125
BM3		0.753	0.431	0.489	0.432
BM3A			0.598	0.646	0.516
BM4				0.493	0.651
BM5					0.709

TABLE 9

COMMUNITY SIMILARITY VALUES, SEPTEMBER 1986 TO MAY 1989, TRIBUTARY TO ELK CREEK, ERIE COUNTY, PENNSYLVANIA

	BM1	BM3	BM4	BM5	BM6
Jaccard Coefficient					
BM1	0.212				
BM3		0.354			
BM4			0.315		
BM5				0.278	
BM6					0.477
Sorensen Coefficient					
BM1	0.349				
BM3		0.523			
BM4			0.479		
BM5				0.435	
BM6					0.646
Percent Similarity					
BM1	10.864				
BM3		23.598			
BM4			12.188		
BM5				16.076	
BM6					29.287
Dissimilarity Index I_1					
BM1	471.294				
BM3		473.433			
BM4			1810.740		
BM5				607.620	
BM6					424.773
Dissimilarity Index I_2					
BM1	65.357				
BM3		68.334			
BM4			246.411		
BM5				82.687	
BM6					64.037
Dissimilarity Index I_3					
BM1	0.949				
BM3		0.900			
BM4			0.914		

BM5				0.908	
BM6					0.840

TABLE 9. (Cont.)

	BM1	BM3	BM4	BM5	BM6
Morisita Index					
BM1	0.090				
BM3		0.229			
BM4			0.116		
BM5				0.065	
BM6					0.229
Horn Index					
BM1	0.188				
BM3		0.439			
BM4			0.278		
BM5				0.260	
BM6					0.494

REFERENCES

American Public Health Association. 1980. Standard methods for the Examination of Water and Wastewater (15th Edition). American Public Health Association, Washington, DC. 1134pp.

APHA et al. 1985. Standard Methods for the Examination of Water and Wastewater. 17th Edition. Section 1005. Pages 1113-1130.

ASTM. 1988. Annual Book of ASTM Standards. Vol. 11.04. 963 pages.

Bartsch, A.F. and William Ingram. 1954. Stream Life and the Pollution Environment. Public Works 90:104-110.

Beck, William M. 1977. Environmental Requirements and Pollution Tolerance of Common Freshwater Chironomidae. U.S.E.P.A. Report No. EPA-600/4-77-024. Cincinnati, Ohio 261 pp.

Bishop, O.W. 1966. Statistics for Biology. Houghton Mifflin Co., Boxton, 182 pp.

Bray, J.R. and J.T. Curtis. 1957. An Origination of the Upland Forest Communities of Southern Wisconsin. Ecol. Monogr. 27 (4):352-349.

Brinkhurst, R.O. 1962. The Biology of the Tubificidae with Special Reference to Pollution. Pges 57 through 66. IN: Dr. Clarence Tarzwell, Biological Problems in Water Pollution, Third Seminar. Report A. Taft Sanitary Engineering Center.

Brower, T.E. and J.H. Zar. 1984. Field and Laboratory Methods for General Ecology. Second Edition. W.C. Brown, Dubuque. 226 pp.

Cairns, John Jr., John S. Crossman, Kenneth L. Dickson and Edwin E. Herricks. 1971. The recovery of damaged streams. The ASB Bulletin 18(3):79-106.

Chew, V. 1977. Comparisons Among Treatment Means in an Analysis of Variance. Agricultural Research Service Publ. ARS/H/6. Beltsville, Maryland., 64 pp.

Compton, Robert R. 1962. Manual of Field Geology. John Wiley and Sons, Inc., New York, NY. 378 pp.

Elliot, J.M. 1977. Some Methods for the Statistical Analysis of Samples of Benthic Invertebrates. Second Edition. Freshwater Biological Association Scientific Publication No. 25. 157 pp.

Gaufin, A.R. 1973. "Use of Aquatic Invertebrates in the Assessment of Water Quality, "Biological Methods for the Assessment of Water Quality, ASTM STP 528 American Society for Testing and Materials:96-116.

Gaufin, A.R. and Clarence N. Tarzwell. 1956. Aquatic Macroinvertebrate Communities as Indicators of Organic Pollution in Lytle Creek. Sewage Ind. Wastes 28(7):906-924.

Goodnight, Clarence J. 1973. The Use of Aquatic Macroinvertebrates as Indicators of Stream Pollution. Trans. of the Amer. Micro. Soc. Vol. 92(1):1-13.

Harris, Todd L. and Thomas M. Lawrence. 1978. Environmental Requirements and Pollution Tolerance of Trichoptera. USEPA Report No. EPA-600/4-78-063. Cincinnati, Ohio. 309 pp.

Hilsenhoff, William L. 1982. Using a Biotic Index to Evaluate Water Quality in Streams. Department of Natural Resources, Madison, Wisconsin, Technical Bulletin No. 132: 22 pp.

Hilsenhoff, William L. 1987. An Improved Biotic Index of Organic Stream Pollution. The Great Lakes Entomologist, Vol 20(1):31-39.

Howmiller, R.P. and M.A. Scott. 1977. An Environmental Index Based on Relative Abundance of Oligochaete Species. JWPCF 49:809-815.

Hubbard, Michael D. and William L. Peters. 1978. Environmental Requirements and Pollution Tolerance of Ephemeroptera. USEPA Report No. EPA-600/4-78-061. Cincinnati, Ohio. 461 pp.

Lagler, Karl L. 1973. Freshwater Fishery Biology. Wm. C. Brown, Co., Dubuque, Iowa. 421 pp.

MacArthur, R.H. 1957. On the Relative Abundance of Bird Species. Proc. Nat. Acad. Sci., Washington, 43:293-295.

Sokal, Robert R. and F. James Rohlf. 1981. Biometry, the Principles and Practice of Statistics in Biological Research, second edition. W.H. Freeman and Co., San Franciso, California. 859 pp.

Surdick, Rebecca F. and Arden R. Gaufin. 1978. Environmental Requirements and Pollution Tolerance of Plecoptera. USEPA Report No. EPA-600/4-78-062. Cincinnati, Ohio. 417 pp.

Sipple, Wm. S. 1988. Wetland Identification and Delineation Manual. Vol. I. Rationale, Wetland Parameters, and Overview of Jurisdictional Approach. USEPA. 30 pages and Appendix A.

Sipple, Wm. S. 1988. Wetland Identification and Delineation Manual. Vol. II. Field Methodology. USEPA 40 pages and Appendices A through F.

Train, Russel E. 1976. Quality Criteria for Water. U.S.E.P.A., Washington, D.C. 256 pp.

Train, Russel E. 1971. Methods for Identifying and Evaluating the Nature and Extent of Nonpoint Sources of Pollutants. USEPA Publication 430/9-73-014. Washington, D.C. 261 pp.

USEPA (1973) See Weber 1973.

USEPA (1988) see Sipple 1988.

USEPA et al (1989). Federal Manual for Identifying and Delineating Jurisdictional Wetlands. 76 pages and 4 Appendices.

Weber, Cornelius. 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. U.S.E.P.A. Report No. EPA 670/4-73-001.

Wilhm, S.E., 1970. Range of Diversity Index in Benthic macroinvertebrate populations. JWPCF 42(2):R221-R224.

TAXONOMIC REFERENCES

Adler, P.H. and K.C. Kim. 1986. The Blackflies of Pennsylvania (Simuliidae:Diptera) Bionomics, Taxonomy, and Distribution. Pennsylvania State Univ., College of Agriculture Bulletin 856:1-88.

Allen, Richard K. and George F. Edmunds, Jr. 1959. A revision of the genus Ephemerella (Ephemeroptera: Ephemerella). The subgenus Tempanogo. The Canadian Entomologist, Vol. XCI: 51-58.

Allen, Richard K. and George F. Edmunds, Jr. 1961. A revision of the genus Ephemerella (Ephemeroptera: Ephemerella) II. The subgenus Caudatella. Annals of the Entomological Society of America. Vol. 54:603-612.

Allen, Richard K. and George F. Edmunds, Jr. 1961. A revision of the genus Ephemerella (Ephemeroptera: Ephemerellidae) III. The subgenus Attenuatella. Kansas entomological Society, Vol. 34(4):161-173.

Allen, Richard K. and George F. Edmunds, Jr. 1962. A revision of the genus Ephemerella (Ephemeroptera: Ephemerellidae) V. the subgenus Drunella. Miscellaneous publication of the Entomological Society of America: 147-179.

Allen, Richard K. and George F. Edmunds, Jr. 1963. A revision of the genus Ephemerella (Ephemeroptera: Ephemerellidae) VI. The subgenus Serratella in North America. Annals of the Entomological Society of America, Vol. 56:583-600.

Allen, Richard K. and George F. Edmunds, Jr. 1963. A revision of the genus Ephemerella (Ephemeroptera: Ephemerellidae) VII. The subgenus Eurylophella. The Canadian Entomologist, Vol. 95:597-623.

Allen, Richard K. and George F. Edmunds, Jr. 1963. A revision of the genus Ephemerella (Ephemeroptera: Ephemerellidae) VIII. The subgenus Ephemerella in North America. Miscellaneous publications of the Entomological Society of America: 244-282.

Arnett, R.H. 1985. American Insects, A Handbook of Insects of America North of Mexico. Van Nostrand Reinhold Co., NY. 850 pp.

Beck, William M. 1979. Biology of the Chironomids. State of Florida Department of Environmental Regulations Technical Series, Vol. 2(1). 58 pp.

Bode, Robert W. 1983. Larvae of North American Eukiefferiella and Tvetenia (Diptera:Chironomidae). New York State Museum Bulletin No. 452, Albany, NY. 40 pp.

Borror, Donald J., Dwight M. Delong, and Charles A. Triplehorn. 1981. An Introduction to the Study of Insects Fifth Edition. Saunders College Publishing, NY. 827 pp.

Bousfield, E.L. 1958. Fresh-Water Amphipod Crustaceans of glaciated North America. The Canadian Field-Naturalist, 72(2):55-113.

Brigham, Allison R., Warren U. Brigham and Arnold Gnilka (Editors). 1982. Aquatic Insects and Oligochaetes of North and South Carolina. Midwest Aquatic Enterprises, Mahomet, Illinois.

Brown, H.P. 1976. Aquatic Dryopoid Beetles (Coleoptera) of the United States. U.S.E.P.A. Water Pollution control Research Series No. 18050 ELDO 4/72, Cincinnati, Ohio. 81 pp.

Bryce, Derek and Alan Hobart. 1972. The biology and identification of the larvae of the chironomidae (Diptera). Entomologist's Gazette, Vol. 23:175-217.

Burch, J.S. 1982. Freshwater snails (Mollusca: Gastropoda) of North America. U.S.E.P.A. Report No. EPA-600/3-82-026. Cincinnati, Ohio. 293 pp.

Claassen, Peter W. 1931. Plecoptera Nymphs of America (North of Mexico). Charles C. Thomas, Publisher, Baltimore, Maryland. 199 pp.

Cranston, P.S. 1982. A key to the larvae of the British Orthocladiinae (Chironomidae). Freshwater Biological Association, Scientific Publication No. 45:1-152.

Conant, Roger. 1975. A Field Guide to Reptiles and Amphibians of Eastern and Central North America, Second Edition. Houghton Mifflin Company, Boston. 429 pp.

Dillon, E.S. and L.S. Dillon. 1972. A Manual of Common Beetles of Eastern North America, Vol. 1 and 2. Dover Publications, Inc., NY. 894 pp.

Edmunds, George F., Jr. 1959. Subgeneric groups within the mayfly genus Ephemerella (Ephemeroptera:Ephemerellidae). Annals of the Entomological Society of America. Vol. 52:543-547.

Edmunds, George F., Jr., Steven L. Jensen and Lewis Berner. 1976. The Mayflies of North and Central America. University of Minnesota Press, Minneapolis, Minnesota. 330 pp

Hilsenhoff, William L. 1975. Aquatic insects of Wisconsin with generic keys and notes on biology, ecology, and, distribution. Department of Natural Resources, Madison, Wisconsin, Technical Bulletin No. 89:52 pp.

Hitchcock, Stephen W. 1974. Guide to the insects of *Connecticut. Part VII. The Plecoptera or stoneflies of* Connecticut. State of Geological and Natural History Survey of Connecticut. Department of Environmental Protection Bulletin 107, Hartford, Connecticut. 262 pp.

Hobbs, Horton, Jr. 1976. Crayfishes (Astacidae) of North and Middle America. Water Pollution Control Research Series *18050 ELD05/72, U.S.E.P.A. Cincinnati, Ohio. 173 pp.*

Johannsen, O.A. 1934-37. Aquatic Diptera. Part I through IV. Memoirs 164, 177, 205, and 210. Cornell University Experimental Station, 1934, 1935, 1936, and 1937, respectively. Reprinted 1969 by Entomological Reprint Specialist, Los Angeles, California.

Klemm, D.J. (ed.). 1985. A Guide to the Freshwater Annelida (Polychaeta, Naidid, and Tubificid Oliyochaeta, and Hirundinae) of North America. Kendall/Hunt Publishing Co., Dubuque, Iowa. 198 pp.

Louton, Jerry. 1982. Lotic Dragonfly (Anisoptera:Odonata) Nymphs of the Southeastern United States:Identification, Distribution and Historical Biogeography. Dissertation, University of Tennessee, Knoxville. 357 pp.

Mason, William T., Jr. 1973. An introduction to the identification of chironomid larvae. Environmental Protection Agency, Cincinnati, Ohio. 89 pp.

McAlpine, J.F., B.V. Peterson, G.E. Shewell, H.J. Teskey, J.R. Bockeroth and D.H. Wood. 1981. Manual of Nearctic Diptera, Vol. 1. Research Branch Agriculture Canada Monograph No. 27. 674 pp.

Merritt, Richard W. and Kenneth W. Cummins. 1984. An Introduction to the Aquatic Insects of North America. Kendall/Hunt Publishing Co., Dubuque, Iowa. 722 pp.

Needham, J.G. and P.W. Claassen. 1925. A Monograph of the Plecoptera or Stoneflies of America North of Mexico. The Thomas Say Foundation of the Entomological Society of America, Vol. II 1-397.

AR301206

Needham, James G. and Minter J. Westfall, Jr. 1954. A Manual of the Dragonflies of North America (Anisoptera):Including the Greater Antilles and the Provinces of the Mexican Border. Univ. of Calif. Press, Los Angeles, Calif. 615 pp.

Pechuman, L.L., Donald W.Webb, and H.J. Teskey. 1983. The Diptera, of True Flies, of Illinois I. Tabanidae. Illinois Natural History Survey Bulletin, Vol. 33(1):1-122.

Pennak, Robert W. 1978. Fresh-water Invertebrates of the United States. John Wiley & Sons, Inc., New York,NY. 803 pp.

Roback, Selwyn. 1985. The immature chironomids of the Eastern United States VI. Pentaneurinia-Genus Ablabesmyia. Proc. of the Acad. Nat. Sci. Philadelphia 137(2):153-212.

Ross, H.H. 1944. The caddisflies, of Trichoptera, of Illinois. Bull. Ill. Nat. Hist. Surv. 23(1).

Simpson, Karl W. and Robert W. Bode. 1980. Common larvae of Chironomidae (Diptera) from New York State streams and river with particular reference to the fauna of artifical substrates. New York State Museum Bulletin No. 439, Albany, NY. 103 pp.

Simpson, Karl W., Robert W. Bode, and Paula Albu. 1983. Keys for the genus Cricotopus adapted from "Revision der Gattung Cricotopus van der Wulp and ihrer Cerwandten (Diptera, Chironomidae)" by M. Hirvenoja. New York State Museum Bulletin No. 450, Albany, NY. 133 pp.

Snoddy, Edward L. and Raymond Noblet. 1976. Identification of theimmatureBlackflies (Diptera:Simuliidae)ofthe South-eastern U.S. with some aspects of the adult role in transmission of Leucocytozoon smithi to Turkeys. South Carolina Agricultural Experimental Station. Bulletin 1057:1-58.

Stark, B.P. and A.R. Gaufin. 1976. the Nearctic Genera of Perlidae (Plecoptera). Miscellaneous Publications of the Entomological Society of America, Vol. 10(1):1-77.

Stewart, K.W. and B.P. Stark. 1989. Nymphs of North American Stonefly Genera (Plecoptera). Entomological Society of America. 460 pp.

Stewart, P.L. and J.S. Loch. 1973. A guide for the identification of two sub-families of larval Chironomidae: The Chironominae and Tanypodinae found in benthic studies in the vicinity of Pine Ralls, Manitoba in 1971 and 1972. Environmental Canada. Technical Report Series No. Cen/T-73-12. 46 pp.

Surdick, R.F. and K.C. Kim. 1976. Stoneflies (Plecoptera) of Pennsylvania: A Synopsis. Pennsylvania State University, College of Agriculture Bulletin 808:1-73.

Tartar, Donald C. 1976. Limnology in West Virginia. Marshall Univ. Bookstore, Huntington, W.Va. 249 pp.

Usinger, R.L. ed. 1963. Aquatic Insects of California. Univ. of California Press, Berkeley and Los Angeles. 508 pp.

Ward, H.B. and G.C. Whipple. 1959. Freshwater Biology. John Wiley and Sons, Inc., New York, NY. 1248 pp.

Waltz, R.D. and W.P.McCafferty. 1979. Freshwater Springtails (Hexapoda:Collembola) of North America. Purdue University Agriculture Experiment Station Research Bulletin No. 960. 32 pp.

Wiekerholm, Torgny (ed.). 1983. Chironomidae of the Holarctic Region Keys and diagnoses. Part 1 - Larvae. Entomologica Scandinavical, Supplement 19:1-457.

Wiggins, Glenn B. 1977. Larvae of the North American caddisfly Genera (Trichoptera). University of Toronto Press, Toronto, Canada. 401 pp.

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